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W. R. Sectorov

The utilization of wind energy has been considered in Russia as part of a construction program of electric power plants. It was decided that wind energy could be used efficiently only in power plants of large capacity, such as were never built previously. /538*

Small wind energy power plants produce continuous current and require banks of storage batteries to control the energy output; they are, therefore, economically unsatisfactory. It is not possible in practice to use continuous current with storage batteries for large capacity power plants if energy has to be transported a considerable distance. A series of studies was therefore undertaken to examine the possibility of wind energy utilization with novel systems. As a result, the feasibility of building three-phase aerodynamic generating plants of the capacity of thousands of kW was considered. The energy produced would be added to high voltage networks, and the aerodynamic power plants would operate in parallel with other generating plants and especially with hydroelectric generators with storage reservoirs which could be used as a backup for aerodynamic generators for periods of low wind.

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*Numbers in the margin indicate pagination in the original foreign text.

The power produced by an aerodynamic generator may vary in practice within short time spans, due to rapid and considerable variations in wind speed. This, however, would not damage the network if many wind-operated power plants were working in parallel. The data obtained showed that wind does not vary simultaneously in various locations, and therefore the overall integral rate of power available from many wind generators connected to each other should be fairly constant.

Before building high-capacity power plants, it was believed necessary to build some experimental plants of medium capacity.

The mobile propeller of a large wind motor has to be fast, and fitted with few blades to make the propeller itself as light as possible. Due to the considerable peripheral speed of the blades, their profile has to be of a design capable of minimizing aerodynamic losses. The dimensions of the propeller, and, therefore, also of the supporting structure, are fairly large. According to local conditions, a power output of 3000 - 5000 kW requires propellers of 100 m diameter. The design has to achieve maximum mechanical resistance with minimum consumption of materials.

The wind generator should also be able to function automatically to avoid high operational expenses. The first experimental plant of this type was built and operated in Balaklawa in Crimea (Figure 1). Its power capacity is of 100 kW, which makes it the largest plant of this type, and the first to use three-phase current.

Crimea is the most suitable location for aerodynamic generators due to its economic conditions and wind pattern. The plants of this type planned for the Crimea will operate in parallel with thermoelectric plants and with one hydroelectric

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plant with a storage capacity of 30 million cubic meters. The average annual wind velocity at the location where the experimental plant of Balaklawa was built is 5.7 m/sec. The plant includes a wind propeller of 30 m diameter proportioned for 130 kW of power, and an asynchronous generator of 1000 kW. Figure 2 shows the diagram of a vertical section of the main part of the plant.

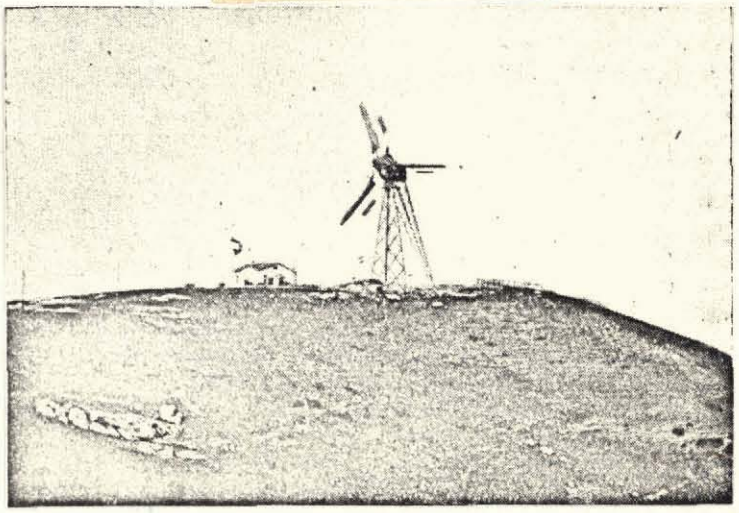

Figure 1. General view of the Balaklawa power plant

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The generator, the gears connecting it with the wind propeller, and the automatic systems are located in the machine room at the top of a supporting structure 25 m high (Figure 3). The electric power, produced at a 220 V voltage, is transmitted (Figure 4) from the generator, through sliding contacts and cables, to the transformer cabin located fairly closely on the ground. There it is transformed to 6.3 kW and tied into the transmission line to a steam turbine plant of much higher capacity located 12 km away.

The wind propeller, 30 m in diameter, has three self-regulated blades built of wood and metal, and lined with a thin steel sheet. It is presently planned to replace them with completely metallic propellers of welded construction. The transverse section of the blade has an aerodynamic profile similar to that of airplane wings.

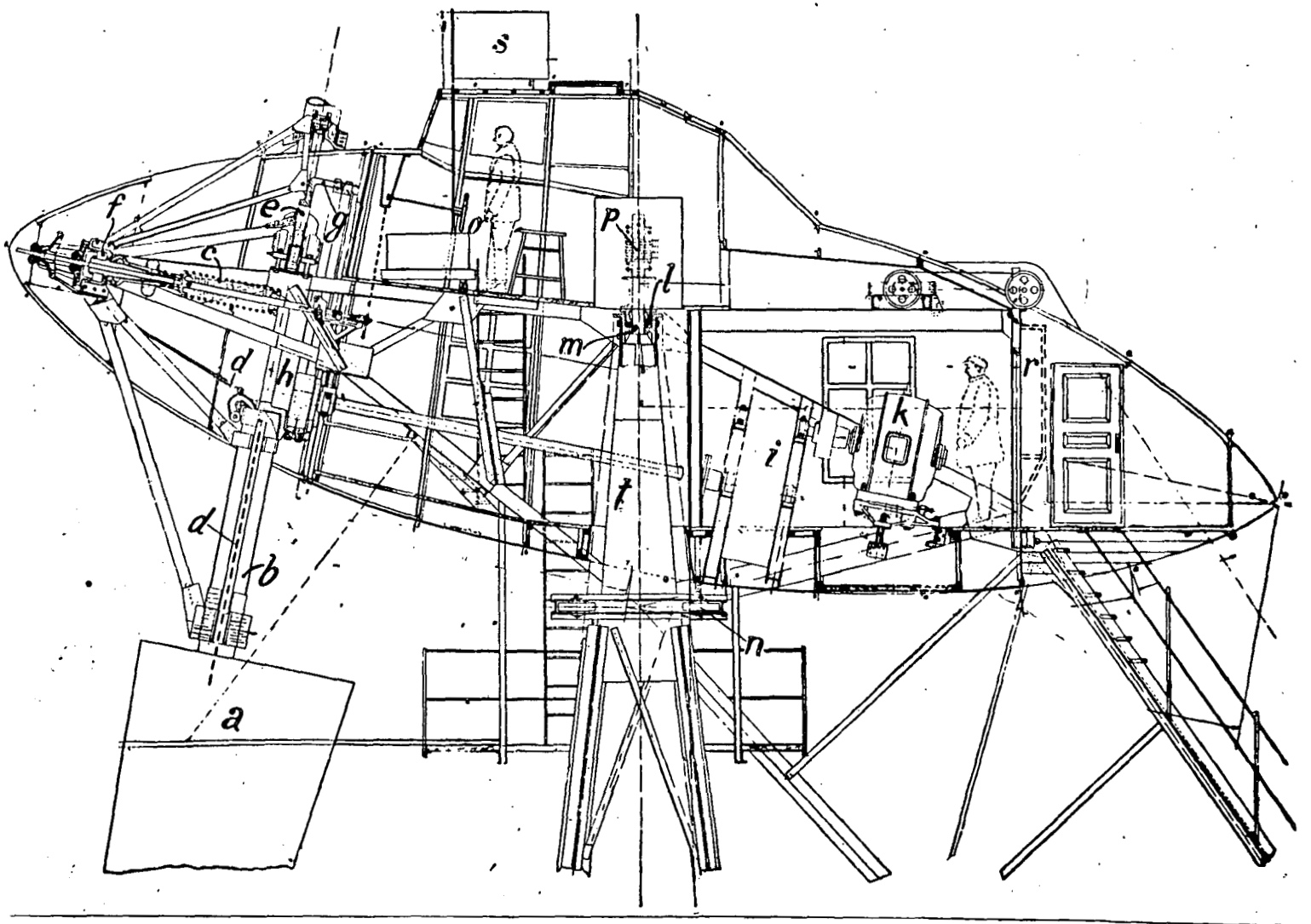

Figure 2. General section of the machine room:

a — propeller blade; b — axis; c — control springs; d — controller levers; e — rollers; f — front support with spheres; g — gear crown; h — gears; i — gears; k — generator; l — spherical pivot; m — axis; n — guide rollers; 0 — starting device; p — sliding contact; r — relay panels; s — directional rudder; t — supporting structure

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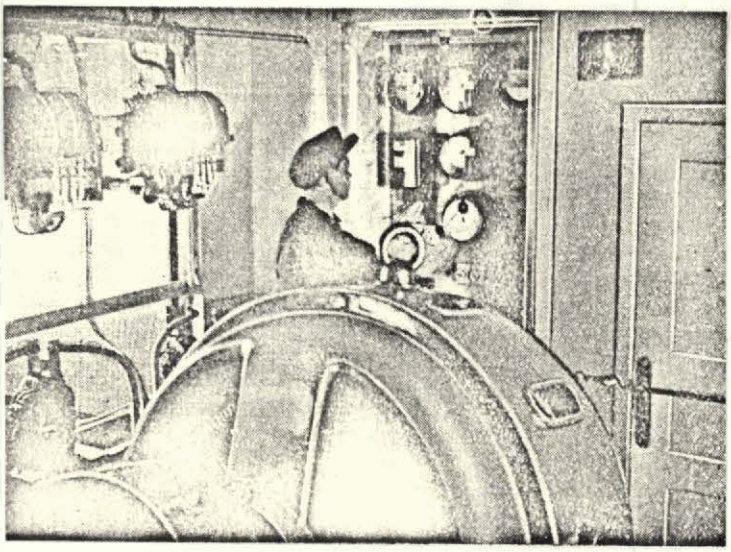

Figure 3. Machine room

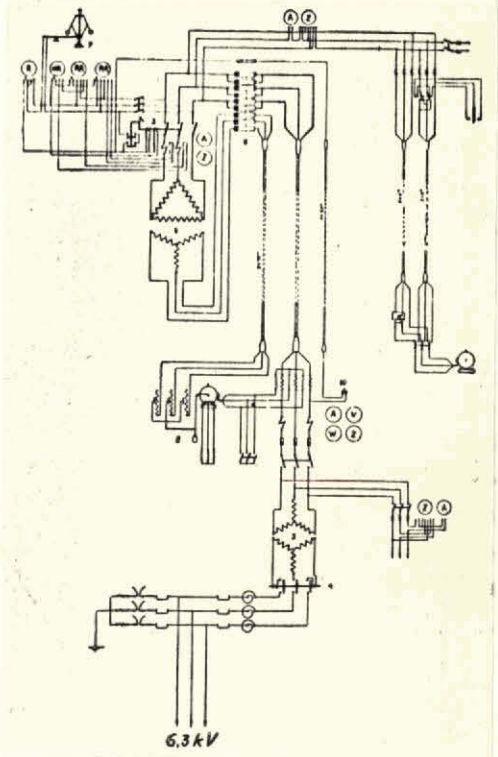

Figure 4. Electric diagram:

1 — asynchronous generator; 2 — sliding contact resistances; 3 — 100 kVA transformer, 200/6300 V; 4 — circuit breaker in oil; 5 — automatic circuit breaker; 6 — sliding contact; 7 — insertion device; 8 — directional rudder; 9 — orienting engine (1.1 kW)

Each propeller (Figure 5) is 11 m long, 2 m wide at the base, and 1 m wide at the tip; the maximum thickness of the propeller is 0.68 m.

Each blade may rotate on two ball bearings around a shaft built with steel tubing 35 cm in diameter. The three axes of the blades are connected by a light steel structure, and are jointed at the base to a strong cast steel ring 34 m in diameter. The wind propeller rotates on this ring, which is supported on its internal circumference by rollers (held by the main structure) and in the front by a support with spheres.

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This ring is provided with gears with wooden teeth connected through a gear box to the generator. The axis of rotation of the propeller, the gears, and the generator is inclined 12° from the horizontal.

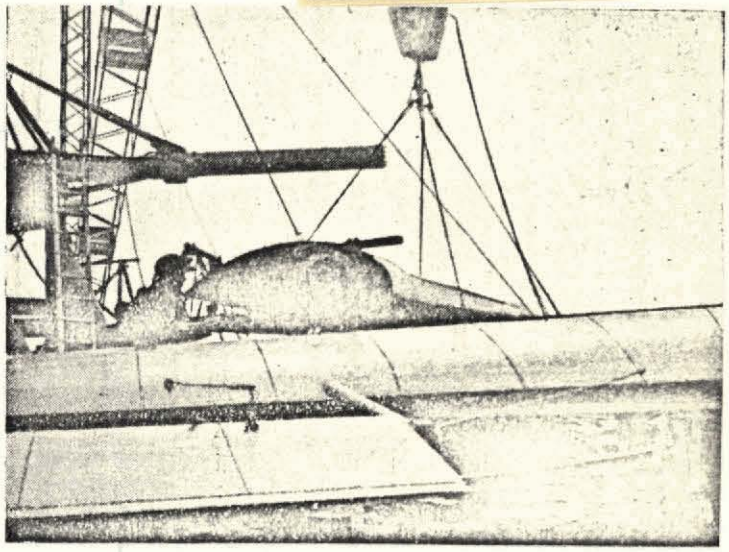

Figure 5. Propeller blade with stabilizer during assembly

The machine room has a skeleton of riveted steel beams resting on a spherical pivot at the top of a large supporting pylon. The machine room with the wind propeller may burn around this spherical pivot, orienting itself always in /540 the direction of the wind. The horizontal forces acting upon the machine room are directed to an axis held by a bronze support and by rollers placed on a horizontal steel ring located at the top of the supporting structure. The machine room is 13 m long, and consists of a skeleton of steel beams covered with wood, lined by thin steel sheets. The generator (Figure 2) is located on the first floor of the machine room; the sliding contacts and the emergency hand commands are located on the second floor.

The front part of the machine room, including the blade-controlling devices, rotates with the wind propeller (Figure 6).

The rotation speed is controlled by mobile masses located inside the blades. These masses develop a centrifugal force which varies in proportion to the velocity of rotation; through a system of connectors and levers, the masses act on the

so-called "stabilizers" with which each blade is provided, varying the angle of incidence of the blades. These devices are located in the front part of the machine room. In the same location, there are some springs whose tension counterbalances the centrifugal force developed by the masses of the controller. The springs bring back the stabilizer to the original position when the rotation velocity decreases. The stabilizer will function correctly only if the blades are well balanced around their radial axis. This is achieved with two carbon steel weights connected to the front part of the blade near its base.

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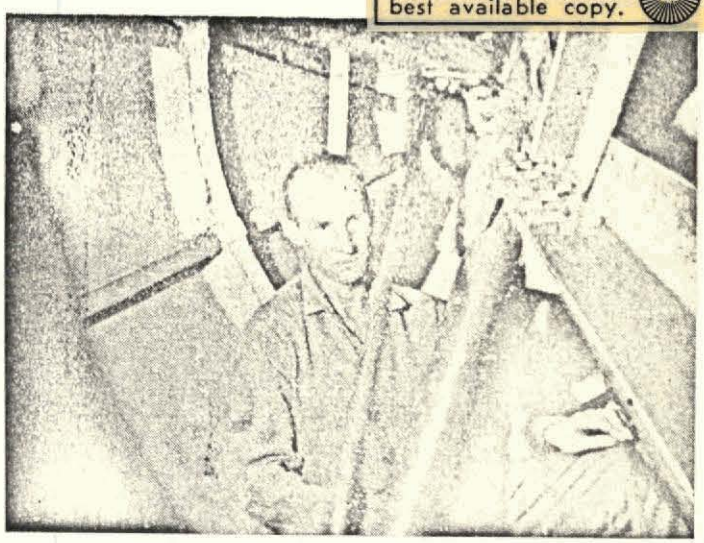

Figure 6. Interior of the rotating front part of the machine room

The controlling device provides the propeller with a constant rotation velocity, even at high wind speeds. The starting or stopping of the wind engine is carried out by setting the stabilizer at suitable angles.

The machine room is connected to an inclined structure which descends to the ground. The structure does not have any supporting purposes, but is used to control the orientation of the machine room in the direction of the wind. This inclined structure is joined near the ground to a rotating platform (Figure 7). A small electric motor of 1.1 kW moves the platform on a circular rail and receives impulses from a directional rudder located at the top of the machine room, so that it keeps orienting the machine room automatically in the direction of the wind. A

ladder was located alongside the connecting inclined structure to permit access to the machine room. The four legs of the supporting structure are immersed for 3 m in foundations composed of 15 m^3 of broken stones. The total weight of this system is 50 metric tons. The heaviest part is the ring of the wind propeller with the blade frames, weighing as much as a ton. A 10-ton crane was used for the assembly of the power plant (Figure 8). The 220 V generator, at 600 rmp, cos $\phi = 0.84$, is provided with a special support which receives the horizontal component of the rotor weight; this is required by the inclined position of the machine. The generating voltage was chosen very low on purpose, for the safety of the personnel assigned to the experimental plant.

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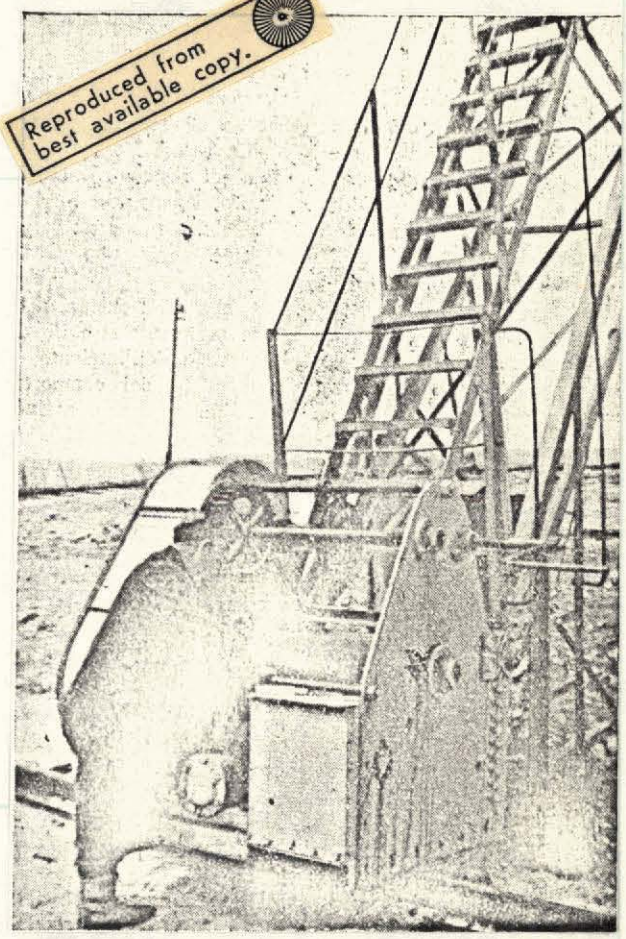

Figure 7. Lower orienting platform with control system

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The overloading of the generator through variations in the rotation velocity was avoided by inserting in the rotor circuit an additional resistance, driven by a small electric motor powered by a current transformer inserted into the main circuit of the generator.

When a synchronous velocity is reached, the generator is automatically inserted in parallel. When the wind dies, the generator is automatically disconnected, but rotation continues with a lower speed, or the system stops until the wind starts again. The automatic part of the system functions with 220 V alternating current to avoid use of storage batteries, decreasing the plant costs.

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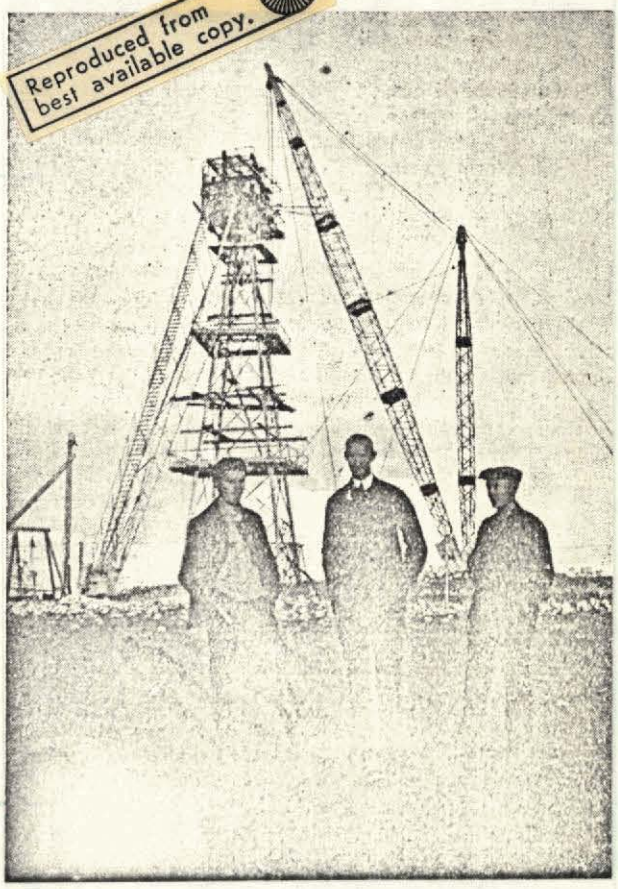

Figure 8. During assembly of the power plant

The generator is inserted on the low voltage side. Due to the fact that the generator is asynchronous, only an approximate coincidence of the rotational velocity with a synchronous velocity is required to insert it in parallel into the network. A mechanical device working through centrifugal force, connected to the axis of the machine, closes the main circuit breaker at a suitable time. To protect the generator, two watt-metric relays and an overload relay were inserted. A block relay stops the centrifugal device after insertion of the generator. The regular function of the automatic devices is monitored in the nearby command cabin on the ground through suitable signal lights on the panel.

At plant start-up, the power developed by various wind speeds was measured, and reported as average values obtained

over 20 minute periods. The wind velocity was measured with an anemometer located at the top of a pole 25 m high, 50 m away from the power plant. No readings were taken when the wind direction was such that the presence of the power plant could have altered the anemometer values.

The power plant was first tested with a propeller rotating at 20 rpm.

After some months of operation, the gear box and the propeller blades were rebuilt to withstand a 30 rpm speed. At present, the power plant functions at such a speed.

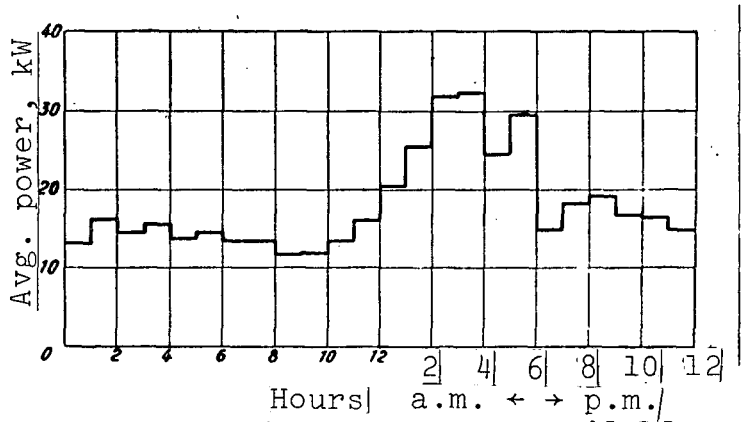

Figure 9. Average power available during an August day

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The tests show that at a speed of 30 rpm, the propeller achieves a power double that obtained at 20 rpm. A power of 100 kW (at 30 rpm) is reached when the wind velocity reaches 11 m/sec.

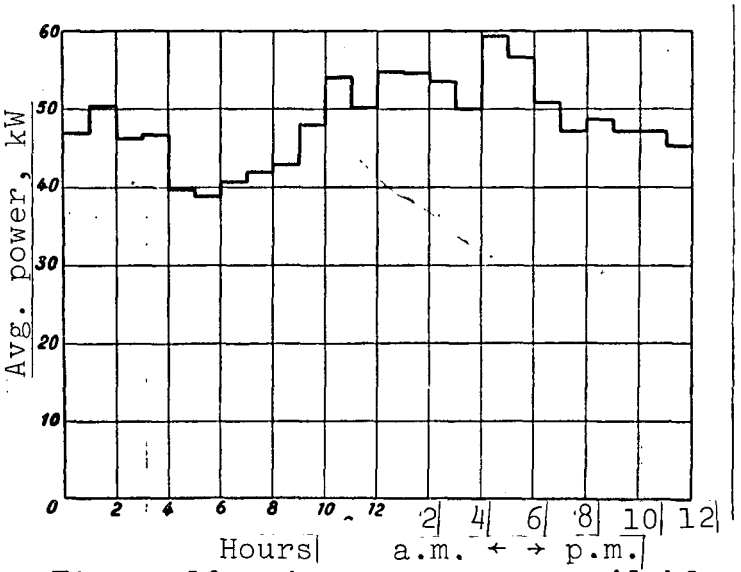

Figure 10. Average power available during a March day.

The power developed by the plant for two characteristic months, August for the summer and March for the winter, are reported in Figures 9 and 10.

Due to the different meteorological conditions in the two seasons, the energy produced in the month of August is lower than the one produced in March; the daily curve showed a maximum' around 3 p.m. In general, the wind velocity increases immediately after sunrise, reaches a maximum velocity in the afternoon, then gradually decreases toward sunset.

The value obtained for the month of March is considerably higher (as in all winter months) and shows lower variations between the daily maximum and minimum.

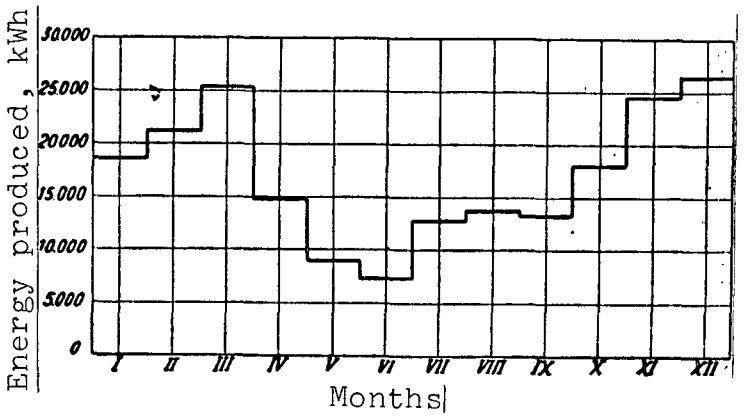

Figure 11. Energy production rate in an average year

In an average year, the experimental plant can produce approximately 200,000 kW/hr. The curve showing the yearly production of energy is reported in Figure 11. The values obtained for the individual months are shown, with a maximum between December and March, and a minimum in May and June; the curve obtained resembles a sine wave.

The results obtained in the first two years of operation of the experimental power plant, in parallel with the electric network of the region, have been very favorable, and support the construction of electro-aerodynamic power plants of much higher capacity.

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16. Abstract

The assembly and functional characteristics of an experimental 100 kW power plant built in Crimea are described. The operating data obtained during the first two years of operation are reported.

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